TITLE OF THE INVENTION

LINEAR COMPRESSOR AND CONTROL METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001]   This application claims the benefit of Korean Patent Application No. 2003-37589, filed June 11, 2003, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002]   The present invention relates to a linear compressor and a control method thereof.

Description of the Related Art

[0003]   A linear compressor is widely used to compress coolant in a freezing cycle such as a refrigerator, etc. The linear compressor measures the magnitude of a stroke of a piston, and controls an operation of the piston by applying a current to a driving motor of the linear compressor based on an analysis of the measured magnitude of the stroke of the piston.

[0004]   FIG. 1 is a cross-sectional view of a position detection sensor of a piston of a conventional linear compressor. As illustrated in FIG. 1, the position detection sensor comprises a sensor body 100, a sensor coil 101, a core support 102, and a core 103.

[0005]   The sensor body 100 includes the sensor coil 101 inside. The sensor coil 101 has a first sensor coil 101a connected in series to a second sensor coil 101b having the same inductance value, size, and number of turns with those of the first sensor coil 101a. The core support 102 made of non-magnetic material supports the core 103 and is combined to the piston (not shown).

[0006]   As the core 103 combined to the piston of the compressor moves back and forth along an inner hole of the sensor body 100, a predetermined reactance is generated in the sensor coil 101 according to the reciprocal movement of the piston.

[0007] FIG. 2 is a diagram of a position detection circuit of the piston of the conventional linear compressor. As illustrated in FIG. 2, two serial sensor coils 101 are connected in parallel with two serial dividing resistors Ra and Rb, and a triangle pulse is inputted as a power source 105. A difference of divided voltages divided by the dividing resistors Ra and Rb is amplified by an amplifier 104 to detect a maximum output voltage according to the piston in which the core 103 moves back and forth starting from a center point between the first sensor coil 101a and the second sensor coil 101b. An analog signal processor 106 receives an output pulse from the amplifier 104 and detects the position of the piston through a predetermined signal process.

[0008] FIG. 3 illustrates an output pulse from the amplifier 104 in FIG. 2 according to the reciprocal movement of the piston of the linear compressor. As illustrated in FIG. 3, the output voltage from the amplifier (line "a") has a linear output property for the reciprocal movement of the piston. The position of the piston can be detected with the output voltage because the output voltage is proportional to the position of the piston.

[0009] However, the sensor circuit of the conventional linear compressor may have the linear property varying an angle of a slope of the graph according to external environment such as a temperature and a pressure. If the sensor circuit of the conventional linear compressor takes the linear property represented by a small angle of the slope like a line "b" due to the external environment, the piston controlled according to a normal operation in a high cooling capacity may have a problem of colliding with a valve of a cylinder. Further variation of cooling capacity may excessively enlarge between a high cooling state and a low cooling state.

SUMMARY OF THE INVENTION

[0010] Accordingly, it is an aspect of the present invention to provide a linear compressor that detects a position of a piston accurately regardless of external environmental conditions.

[0011] Additional aspects and advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

[0012] The foregoing and/or other aspects of the present invention are achieved by providing a linear compressor having a core combined to one end of a piston to detect a position of the piston reciprocally moving up and down, and a first sensor coil and a second sensor coil

detecting the position of the core, wherein the core comprises an upper core having a length shorter than one half of the length of the first sensor coil and the second sensor coil in series.

[0013] According to an aspect of the invention, the core includes an upper core; and a lower core spaced apart from the upper core by a predetermined distance.

[0014] According to an aspect of the invention, a middle point between the upper core and the lower core passes a middle point between the first sensor coil and the second sensor coil when the piston passes a center point of a reciprocal moving path of the piston.

[0015] According to an aspect of the invention, the linear compressor includes a first branch comprising the first sensor coil and a predetermined first dividing resistor connected in series; a second branch comprising the second sensor coil and a predetermined second dividing resistor connected in series; a source power applied to the first branch and the second branch; and a voltage comparator receives voltages applied to the first dividing resistor and the second dividing resistor as inputs.

[0016] According to an aspect of the invention, the voltage comparator receives voltages taken from the opposite terminals of each of the first sensor coil and the second sensor coil as the inputs.

[0017] According to an aspect of the invention, the linear compressor further includes a controller controlling the position of the piston based on a top dead center detected by measuring a difference of time taken for a center point of the upper coil to pass a coil origin, or a middle point between the first sensor coil and the second sensor coil, according to reciprocal movement of the piston.

[0018] According to an aspect of the invention, the linear compressor further includes a controller controlling the position of the piston based on a top dead center detected by measuring a difference of time taken for the center point of the upper coil to pass the coil origin, or the middle point between the first sensor coil and the second sensor coil, according to the reciprocal movement of the piston.

[0019] According to an aspect of the invention, the linear compressor includes a controller controlling the position of the piston by detecting a top dead center on a basis of a difference of

time taken for an output of the voltage comparator to become 0 twice as the piston is positioned near the top dead center.

[0020] According to an aspect of the invention, the linear compressor includes a controller controlling the position of the piston by detecting a top dead center on a basis of a difference of time taken for the output of the voltage comparator to become 0 as the piston is positioned near the top dead center.

[0021] According to an aspect of the invention, the linear compressor includes a controller detecting an offset value indicating the degree of how far a center point of reciprocation movement of the piston is off from a predetermined center point by measuring a difference of time taken for a center point of the upper core to pass a coil origin positioned at a middle point between the first sensor coil and the second sensor coil, and by measuring a difference of time taken for a center point of the lower core to pass the coil origin according to the reciprocal movement of the piston.

[0022] According to another aspect of the present invention, the above and other aspect may be also achieved by providing a control method of a linear compressor having a core combined to one end of a piston moving up and down, and a first sensor coil and a second sensor coil detecting a position of the core, including forming the core comprising an upper core and a lower core being spaced from each other; detecting a top dead center of the piston by measuring a time taken for a center point of the upper core to pass a middle point between the upper coil and the lower coil according to reciprocal movement of the piston; and controlling a position of the piston on a basis of the top dead center.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The above and/or other aspects and advantages of the present invention will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompany drawings of which:

FIG. 1 is a cross-sectional view of a position detection sensor for a piston of a conventional linear compressor;

FIG. 2 is a diagram of a position detection circuit for the piston of the conventional linear compressor;

FIG. 3 is a waveform of an amplifier according to reciprocal movement of the piston of the conventional linear compressor in FIG. 2;

FIG. 4 is a cross-sectional view of a position detection sensor for a piston of a linear compressor according to an embodiment of the present invention;

FIG. 5 is a block diagram of a position detection circuit for the piston of the linear compressor according to the embodiment of the present invention;

FIGS. 6A-6C and 7A-7C are waveforms of a voltage comparator according to reciprocal movement of the piston of the linear compressor;

FIG. 8 is an output waveform of the voltage comparator according to the position of the piston of the linear compressor according to the embodiment of the present invention;

FIGS. 9A and 9B illustrate the position of the piston according to the embodiment of the present invention corresponding to passage of time.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0024]   Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments are described below to explain the present invention by referring to the figures.

[0025]   FIG. 4 is a cross-sectional view of a position detection sensor for a piston of a linear compressor according to an embodiment of the present invention. As illustrated in FIG. 4, a position detection sensor 40 comprises a sensor body 1, a sensor coil 2, a core support 3, and a core 4.

[0026]   The sensor body 1 includes a sensor coil 2 inside. The sensor coil 2 comprises a first sensor coil 2a connected in series with a second sensor coil 2b. The first sensor coil 2a and second sensor coil 2b have the same inductance value, size, and number of turns. The core support 3 is made of non-magnetic material that supports the core 4 and is combined to the piston (not shown).

[0027]   The core 4 comprises an upper core 4a and a lower core 4b respectively having a short predetermined length. The upper core 4a and lower core 4b are spaced apart from each other by a predetermined distance. The length of each of the upper core 4a and the lower core 4b should be preferably less than one half of the length of the sensor coil 2 comprising the first

5

sensor coil 2a and the second sensor coil 2b. The upper core 4a is connected to the lower core 4b by the core support 3.

[0028] As the core 4 combined to the piston of the compressor moves back and forth along an inner hole of the sensor body 1, a predetermined reactance is generated in the sensor coil 2 according to the movement of the core 4 within the inside of the sensor coil 2.

[0029] FIG. 5 is a block diagram of a position detection circuit for the piston of the linear compressor according to the embodiment of the present invention. As illustrated in FIG. 5, the position detection circuit comprises the first sensor coil 2a, the second sensor coil 2b, a first dividing resistor R1, a second dividing resistor R2, a power source 10, a voltage comparator 11, a digital signal processor 12, and a controller 13.

[0030] The power source 10 applies power to a first branch having the first sensor coil 2a and the first dividing resistor R1 connected in series, and to a second branch having the second sensor coil 2b and the second dividing resistor R2 connected in series.

[0031] The voltage comparator 11 receives voltages taken from a corresponding terminal of each of the first dividing resistor R1 and the second dividing resistor R2 as a comparison signal V+ and a comparison signal V-, respectively. Also, the voltage comparator 11 may receive voltage taken from a terminal of each of the first sensor coil 2a and the second sensor coil 2b.

[0032] The digital signal processor 12 transmits a rectangular pulse to the controller 13 according to an output of the voltage comparator 11, and then the controller 13 controls a driving motor (not shown) of the linear compressor based on the rectangular pulse.

[0033] FIGS. 6A through 6C and 7A through 7C are input waveforms of the voltage comparator 11 according to reciprocal movement of the piston of the linear compressor.

[0034] FIG. 6A represents a triangle pulse from the power source 10, and FIG. 6B represents waveforms inputted to a positive terminal and a negative terminal of the voltage comparator 11.

[0035] FIG. 6B represents the input waveform of the voltage comparator 11 when a center point (will be referred to as an upper core origin) of the upper core 4a passes a middle point (will be referred to as a coil origin) between the first sensor coil 2a and the second sensor coil 2b, or compression when the piston reaches near a top dead center during a compression stroke. If

6

the triangle pulse is applied from the power source 10, an inductance L2 of the second sensor coil 2b becomes greater than an inductance L1 of the first sensor coil 2a during the negative portion of the triangle pulse input. Accordingly, the input waveform V- input into the negative terminal of the voltage comparator 11 has a longer time delay than the time delay of the input waveform V+ input into the positive terminal of the voltage comparator 11.

[0036] As illustrated in FIG. 6C, the digital signal processor 12 generates a rectangular waveform Vd having a high level when the input waveform V+ of the positive terminal of the voltage comparator 11 is greater than the input waveform V- of the negative terminal.

[0037] FIG. 7A through 7C are waveforms when the upper core origin is inclined toward the first sensor coil 2a from the coil origin. In this case, the inductance L1 of the first sensor coil 2a becomes greater than the inductance L2 of the second sensor coil 2b during the negative cycle of the triangle input. Accordingly, the input waveform V+ input into the positive terminal of the voltage comparator 11 has a longer time delay in comparison with the input waveform V- as shown in FIG. 7B. FIG. 7C illustrates a rectangular waveform Vd output from the digital signal processor 12 corresponding to the waveforms in FIG. 7B.

[0038] FIG. 8 is a waveform that is output from the voltage comparator 11 according to a position of the piston of the linear compressor according to an embodiment of the present invention. As illustrated in FIG. 8, a waveform "c" has three zero points and corresponds to the input waveforms illustrated in FIGS. 6B and 7B.

[0039] The output waveform of the voltage comparator 11 passes through a first zero point as a middle point (will be referred to as a core origin), between the upper core 4a and the lower core 4b, passes the coil origin.

[0040] An output V_0 of the voltage comparator 11 has a second zero point in a top area if the upper core origin of the upper core 4a passes the coil origin, and the output V_0 of the voltage comparator 11 has a third zero point in a bottom area if the center point of the lower core 4b passes the coil origin.

[0041] When the output V_0 of the voltage comparator 11 is at the second zero point during the compression stroke of the piston, the piston is at a top origin position. The top origin position is also passed during an extension stroke. The top origin is a fixed position, and an

exact position of the top dead center can be estimated by measuring the amount of time that the piston takes to pass the top origin twice, once during the compression stroke and once during the extension stroke.

[0042]   Also, the position of the top dead center can be estimated based on the duration of time that passes before the output V_0 of the voltage comparator 11 passes the second zero point having a zero output in the top area twice.

[0043]   A waveform "d" in FIG. 8 is the output waveform V_0 of the voltage comparator 11 when the external environmental conditions of the sensor such as a temperature, and pressure have changed. The waveform "d" illustrates that the zero points do not vary regardless of changes to the external environment. Accordingly, the top dead center can be found accurately on the basis of the top origin that is not affected by the external environment, and the position of the piston can be controlled based on the aforementioned.

[0044]   FIGS. 9A and 9B illustrate magnitude of a stroke of the piston of the linear compressor according to an embodiment of the present invention corresponding to passage of time. As illustrated in FIG. 9A, the stroke of the piston appears as a sine waveform "E" according to the passage of the time. The magnitude of the stroke of the piston appears as a sine waveform "F", in a case where the core origin does not match to the coil origin and gets inclined to the top dead center, that is, an offset occurs, when the piston is in a middle point of a reciprocal moving path.

[0045]   Even for such cases, the stroke of the piston can be controlled because the top dead center can be measured based on a measured time that the piston takes to pass the top origin twice.

[0046]   If the position of the lower core 4b is inclined near to the coil origin, the bottom origin is adjusted upward to the coil origin in FIG. 9A. With such a configuration, an offset value indicating the degree that the center point of the reciprocal moving path of the piston is off from a predetermined center point can be detected by measuring an elapsed time that the piston takes to pass the altered bottom origin twice and by measuring the time that the piston takes to pass the top origin twice.

8

[0047]　　FIG. 9B illustrates the output waveform Vd of the digital signal processor 12 corresponding to curved lines E and F in FIG. 9A.

[0048]　　Also, even if the core 4 includes only the upper core 4a, the output waveform V_0 of the voltage comparator 11 has the second zero point in the top area, and the top dead center can be estimated in the same manner on a basis of duration for passing the top origin.

[0049]　　The position of the piston of the linear compressor can be measured and controlled according to this embodiment of the present invention.

[0050]　　Although a few embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in this embodiment without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.